ological individual which I have tried to present.

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THE BASIS OF INDIVIDUALITY IN ORGANISMS FROM THE STANDPOINT OF CYTOLOGY AND EMBRYOLOGY[1]

I

An individual in the broadest sense is any animate or inanimate thing which is regarded as a unit. In this sense the electron, atom, molecule, crystal, biophore, determiner, chromomere, chromosome, nucleus, centrosome, cell, organ, system, person, corm, state, species, etc., are individuals. In all but the simplest units individuality involves organization, that is differentiation into parts and integration into a single whole. A fundamental property of any unit is its separateness or separableness, from other units, and yet no unit is completely independent. Biological units are separate in both structure and function from other units and yet they are related to others and these relations may be of such a sort that they constitute units of a higher order. Organic individuality of whatever order is dependent upon separateness of structure, of growth and of division. But while all vital units are separate or separable, they vary greatly in independence from the parts of a cell which are incapable of independent life to cells and to persons which are capable by themselves of maintaining life processes. The failure to distinguish between separateness and independence has been a fruitful source of misunderstandings in biological controversies.

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An organic individual then is any unit capable of manifesting the properties of life. The simplest and most fundamental properties of life are: (1) Metabolism, especially assimilation and growth, and (2) Reproduction by division. Every vital unit manifests both of these properties from the ultra-microscopical units of living matter to its more complex aggregates. To these two properties there is usually if not invariably added (3) sensitivity or the capacity of responding to stimuli, frequently in a beneficial or adaptive way. An organic individual then is capable of assimilation, growth and division and it may be irritable or sensitive. This definition can not be made more specific, for individuality is not a hard and fast thing. There are all degrees of organic individuality from the simplest and smallest units of living matter to the largest and most complex. As applied to human beings and their organization into society, the word "individuality" has come to have a metaphysical and mystical significance and not infrequently this mysticism has been extended to all forms of individuality.

1. *Individuality of Ultra-microscopic Units of Living Matter.*—Long ago Brücke (1861) maintained that protoplasm must be composed of ultra-microscopic units capable of assimilation, growth and division and these units he called "the smallest living parts." Many students of the subject since that time have postulated similar units; such as the "physiological units" of Spencer, the "gemmules" of Darwin, the "plasomes" of Wiesner, the "pangenes" of de Vries, the "idioblasts" of O. Hertwig, the "biophores" and "determinants" of Weismann, and the "factors," "determiners" and "genes" of many students of heredity. Recent studies of Men-

delian inheritance have furnished an extraordinarily complete demonstration of the existence of such inheritance units and of their persistence generation after generation. Such units are individuals in that they are separate from, though dependent upon, other units and in that they apparently manifest the fundamental vital processes of assimilation, growth and division.

2. *The Individuality of Parts of Cells.*—Many parts of a cell, such as the chromomeres, chromosomes, plastids, and in some instances at least, the centrosomes and plastosomes are also individuals in this same sense. The question of the individuality of chromosomes and centrosomes has given rise to much controversy chiefly because the term "individual" has not been clearly defined. No one doubts that chromosomes have the power of assimilation, growth and division and the only question at issue is as to whether they disintegrate at the close of every division and are formed anew at the beginning of the succeeding division. Now that individual chromosomes have been traced right through the entire resting period in several cases, there is no longer any reason to doubt that chromosomes do in some instances preserve their individuality. The fact that they, like all other forms of living matter, undergo metabolic change, receiving food substances on the one hand, and building them up into their own substance, and on the other hand, giving off the waste products of their own destructive metabolism—in short that the materials of which they are composed are undergoing continual change—does not obscure the individuality of a chromosome any more than a similar process obscures the individuality of a man. That which persists amid all metabolic changes in both the chromosome and the man is not identical atoms or molecules, but an identical organization or plan or relation of subordinate parts to one another.

In my experience the same is true of centrosomes; they also undergo growth and division, are continuous from cell generation to cell generation, and do not arise *de novo* from "cytasters," which are only temporarily isolated portions of archiplasm or kinoplasm, though they are genetically related to achromatic constituents of the nucleus. In all probabilities there are other units in the cell which preserve a like individuality, as, for example, plastids and plastosomes. All such parts of a cell have an individuality of their own, in that they are separate though not independent, and have the properties of assimilation, growth and division.

3. *Individuality of Cells.*—The individuality of ultra-microscopic units and of visible parts of cells is of a different order from that of entire cells. The former, though separate, are yet so dependent on other units as to be incapable of independent existence. In the cell for the first time we find an organic individual sufficiently independent to carry on by itself all fundamental processes of life. Protista, germ cells, embryonic cells and tissue cells show this independence in varying degrees, and yet of course, no cell and no higher organism is absolutely independent of other organisms or of the environment. In short, independence is a relative term and is no necessary part of individuality.

In the union of the egg and sperm cells in fertilization, the cells lose their independence as cells, though the separateness of parts of these cells may persist. There is here the merging of two cell individualities into one, just as in the reverse process of cell division there is the merging of one cell individuality into two. But so far as

separateness and independence are concerned, the fertilized egg cell or oosperm, and the fully formed organism into which it develops are one and the same individual, though differing greatly in complexity. This fertilized egg fuses with no other cells, it takes into itself no ready-made living substance, but manufactures its own protoplasm from food substances; it carries on its own processes of assimilation, growth and division—in short it is a separate and highly independent living thing which may be designated as an organism.

The complexity of any individual is proportional to the number of *unlike units* which constitute it, and this is as true of a chromosome as it is of a person. A common mistake is the supposition that complexity is determined by the *number* of cells, whether like or unlike, composing a body. On the other hand, as Whitman showed, the body of a one-celled protozoan may be as complex as that of a many-celled metazoan; and every zoologist knows that a mouse is as complex as an elephant, though it is composed of a much smaller number of cells. In the development of an egg cell the complexity of the entire individual increases only as the number of unlike parts increases; mere duplication of like parts leads to increase in size, but not to increase in complexity.

Only in relatively simple units is division non-differential so that both products are entirely alike, as is probably the case in all ultra-microscopic units, in cell organs and in very simple cells. In more complex individuals, whether they are cells or cell aggregates, the products of division usually differ from one another, at least when first formed, and in the most complex individuals division of the entire organism is more or less completely abandoned. In the division of a protozoan like *Paramecium* the two products are at first unlike, but as they continue to separate they become alike by a process of regulation. If these products of fission did not separate and did not undergo regulation, there would be formed a number of cells, organically connected and differing from one another in structure and function. This is just what happens in the cleavage of the egg of a metazoan; the original organism divides into many cells each of which is more or less dependent upon others. The original individual is broken up into many parts, but it is evident that there is one individual of the grade which may be called an organism at the beginning of development and just one and no more at its end; indeed the organism is the same individual from the oosperm to the end of life, irrespective of the number of cells or subordinate parts of which it may be composed. However, if cleavage cells separate and undergo regulation, as in the case of *Paramecium*, we may have as many organisms as there are separate parts. This applies to the division of groups of cells or body parts as well as to cleavage cells. If cells or parts of cells separate off which are not capable of regulation and of continued life, they do not form independent individuals.

II

If now we inquire what causes an individual of any grade to divide and thus to give rise to two new individuals we are compelled to confess that we do not know in any instance. The cause of the division of a centrosome or chromosome or nucleus or cell is as mysterious as the cause of division of a hydroid or worm. The division of the cell has been studied more fully than that of any other individual. We know that the centrosome divides before the nucleus and the latter before the cell body, but while we know that a cause must precede its effect we can not say *post hoc*

ergo propter hoc. The fact is we do not know what causes the division of a centrosome, or chromosome or cell or a many-celled organism.

Spencer held that since the volume of any organic body increases as the cube of its diameter, whereas its surface, through which it must receive nutriment, increases only as the square, it must divide after reaching maximum size in order to restore a proper ratio of surface to volume; but although this may be true in general, the sizes of cells, or of other organic bodies, vary enormously and it does not seem possible to explain all these differences in size in accordance with Spencer's hypothesis alone; furthermore, there is no indication of the mechanism by which this general need to divide actually causes division. Boveri assumed that chromosomes and nuclei grow until they are equal in size to the parent structures from which they came and that they then divide; but this is far from being true in some cases. In the cleavage of the egg the cells, nuclei, chromosomes and centrosomes progressively grow smaller, and this not at any uniform rate for all cells, some growing smaller much more rapidly than others. R. Hertwig finds the cause of cell division in the preservation of a proper ratio between the nuclear volume and the cell volume, but as I have shown there is no contant nucleus-plasma ratio since this ratio differs greatly even in different cells of the same embryo. Strassburger held that the cause of cell division was to be found in the limit of the "working sphere of the nucleus," and that when in the growth of the cell this limit was reached, the cell divided; but again it may be objected that there is no fixed limit to the "working sphere of the nucleus" even in the same animal; in some cells of *Crepidula* the volume of the nucleus at the time of division is three times that of the cytoplasm, in others the cytoplasm is fifteen times that of the nucleus. Apparently no single one of these factors is the determining cause of cell division, and it seems probable that the latter is brought on by the coincidence of several more or less independent factors.

In a series of contributions and in two recent books Child has emphasized the importance of polar "gradients of metabolism" as the basis of organic individuality. He finds, for example, that metabolism is most active at the anterior or head ends of certain protozoa, hydroids, flatworms, embryos, etc., and that it becomes less active toward the opposite ends. Regions of higher activity "dominate" those of lower activity, and whenever the metabolic activity of the head region ceases to dominate the entire body, secondary regions of higher metabolic activity appear and may lead to division, one individual thus becoming two; the basis of individuality is thus reduced to polar gradients in metabolism. But in existing organisms physiological gradients are associated with corresponding gradients in material structure, since structure and function are inseparable in living things. Disembodied functions are as unknown in biology as are disembodied spirits. Doubtless gradients of metabolism as well as of growth, division, differentiation and sensitivity exist in organisms; but there is good reason to maintain that such gradients in physiological processes are associated with corresponding gradients in material substances, and this is merely to hold that axial differentiations, both physiological and morphological, exist in organisms. That such differentiations frequently accompany the division of cells or of multicellular organisms is well known, but that they cause these divisions is unproved. The simplest individuals, such as chromo-

meres, chromosomes and centrosomes, divide into approximately equivalent halves; in many cells and cell aggregates the division halves are not equivalent, though they may later become so by regulation. It seems probable that, apart from this difference, the causes of division of all grades of individuals, from the simplest to the most complex, will be found to be similar. Individuals capable of independent existence arise either by equivalent division, as in bacteria, ameba and the germ cells of many-celled organisms, where subsequent regulation is slight, or by non-equivalent division followed by a large amount of regulation, as in the fission of many higher protozoa and metazoa. The basis of individuality in the one case is division with slight regulation, in the other division and considerable regulation.

Individuals, therefore, come into existence by the division of previously existing individuals, though it is conceivable that they may also be formed anew by the synthesis of smaller units; the former is what is known as *biogenesis,* the latter *abiogenesis.* Likewise individuals go out of existence by the division of one individual into two, with consequent loss of the original individuality, that is in reproduction, and also by the disintegration of an individual into its constituent units, namely in death.

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RESOLUTIONS IN MEMORY OF RUDOLPH AUGUST WITTHAUS AND CHARLES CLIFFORD BARROWS

The faculty of the Cornell University Medical College has adopted memorials on the deaths of two of its members, Professor Witthaus and Professor Barrows. The memorials, which were drawn up by Warren Coleman, W. Gilman Thompson and W. M. Polk, are as follows:

In the death of Dr. Rudolph August Witthaus, emeritus professor of chemistry, on December 19, 1915, after a long illness, the medical faculty of Cornell University sustained the loss of one of its most famous men.

Dr. Witthaus was graduated from Columbia University in 1867 and received his Master's degree in 1870. He continued his studies at the Sorbonne and the Collège of France. In 1875 he obtained the degree of M.D. from the University Medical College (New York University). He occupied chairs of chemistry and toxicology, chemistry and physiology, and chemistry and physics in the universities of Vermont, Buffalo and the University Medical College (New York University). In 1898 he was called to the chair of chemistry and toxicology in Cornell University Medical College and occupied this position until his retirement, for age, in 1911. Since 1911, he had been emeritus professor of chemistry in Cornell University Medical College.

Dr. Witthaus's career was most notable perhaps for two circumstances, the eminence to which he rose and for the fact that the subject in which he acquired fame was, in his youth, the plaything of a dilettante. His interest in chemistry dated back to his college days when he converted a room in his father's stable into a laboratory where he amused himself with the study of chemical problems. Reverses in fortune soon compelled him to seek a livelihood in what had been his hobby.

In his riper years he was without a peer as a medico-legal expert. His services were often sought by the state in criminal trials involving toxicological questions and his testimony was always an important, if not the leading factor, in the verdicts of the juries. He made what is probably the most complete catalogue of reported cases of poisoning in existence.

Dr. Witthaus was a prolific, as well as a convincing, writer. His text books, "Essentials of Chemistry," "General Medical Chemistry," "Manual of Chemistry" and "Laboratory Guide in Urine Analysis and Toxicology," were much in demand and passed through numerous editions. He contributed articles on toxicological subjects to Wood's "Handbook of the Medical Sciences," and edited "Witthaus and Becker's Medical Jurisprudence" the fourth volume of which he wrote.

He was a Fellow of the American Association for the Advancement of Science and the Academy